The Use of Travel Time to Measure Geographic Accessibility to Breast Screening Services in New South Wales, Australia

Deborah van Gaans,1 Neil Coffee,2 Theo Niyonsenga,2 Catherine Miles,3 Matthew Warner-Smith,3 Mark Daniel,2 David Roder4 and Daniel J. Weiss5

1School of Social Sciences, The University of Adelaide, Adelaide, South Australia, Australia.
2Centre for Research and Action in Public Health (CeRAPH), University of Canberra, Canberra, Australian Capital Territory, Australia.
3Business Intelligence and Information Systems, Cancer Institute New South Wales, Alexandria, New South Wales, Australia.
4Australian Centre for Precision Health, University of South Australia, Adelaide, South Australia, Australia.
5Big Data Institute, Nuffield Department of Medicine, University of Oxford, Oxford OX3 7FY, UK.

E-mails: Deborah.vangaans@adelaide.edu.au, neil.coffee@canberra.edu.au, Theo.niyonsenga@canberra.edu.au, Catherine.miles@health.nsw.gov.au, matthew.warner-Smith@cancerinstitute.org.au, Mark.daniel@canberra.edu.au, David.roder@unisa.edu.au and Dan.weiss@bdi.ox.ac.uk

Received for publication May 20, 2019.

Abstract

In 2018, the World Health Organization set a goal to increase the proportion of breast cancers identified at an early stage. Early detection allows for more effective treatment and a reduction in the risk of death from breast cancer. Poor access may restrict participation in screening, diagnostic and treatment services, with flow-on effects on stage at diagnosis and survival. This paper presents spatial analysis of travel time to breast screening services in New South Wales, Australia to measure the geographic accessibility of services to the population they serve. The travel time surface was created using a friction surface that estimates the time required to traverse each pixel within a global grid, and a least cost path algorithm to find the optimised route from each output pixel to the breast screen services. The friction surface was derived using a set of input layers, with the roads layer being the most critical for defining travel times. The generated surface of travel time to breast screen services in New South Wales has shown that over 90% of the population are within 20 min’ drive time of either a fixed or mobile breast screen service and that 100% of the population are within 100 min’ drive time of a breast screen service. The ability to identify and measure spatial variations in geographic accessibility via travel time is vital to plan breast screening services and reduce inequalities in health outcomes.

Keywords

Travel time, Accessibility, Equity, Health service, Mammography, Breast screen.

Breast cancer is the leading cancer in women worldwide in both developed and developing countries (World Health Organization, 2014). In resource-constrained settings with very limited health system capacity and lack of early-detection programmes, the majority of women with breast cancer are diagnosed in the late stages and the overall five-year survival rate is very low, with a range of 10 to 40% (World Health Organization, 2014). The World Health Organisation (2018) has set a goal to increase the proportion of breast cancers identified at an early stage, allowing for more effective treatment to be used and reducing the risks of death from breast cancer. Research by Roder et al. (2008) found that participation in screening was associated with a breast cancer mortality reduction of between 30 and 41%, depending on assumptions about screening self-selection bias.
The BreastScreen Australia programme was introduced in 1991 and is funded and coordinated jointly through federal, state, and territory governments (Australian Government Department of Health and Ageing, 2009). The national BreastScreen Australia programme provides free screening mammograms at two-yearly intervals for women without symptoms of breast cancer. The programme actively targets women aged 50 to 69 years, however women aged 40 to 49 years and women aged over 70 years are also eligible to attend (Australian Government Department of Health and Ageing, 2009). The programme has a target participation rate of 70%, however in 2004 to 2005, 1,614,871 women participated in screening mammography through the BreastScreen Australia programme – a participation rate of 56.2% (of these women, 1,188,720 (74%) were in the target age group of 50-69 years) (Australian Institute of Health and Welfare, 2008). Preliminary participation data for 2015 to 2016 show that 1,772,603 women aged 50 to 74 participated in BreastScreen Australia, which is 54.8% of the target population (Table 1) (Australian Institute of Health and Welfare, 2017).

Table 1. Participation of women aged 50 to 69 in BreastScreen Australia, 1996–1997 to 2015–2016.

<table>
<thead>
<tr>
<th>Reporting period</th>
<th>Participants (a)</th>
<th>Population (b)</th>
<th>Crude rate (c)</th>
<th>AS rate (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996–1997</td>
<td>845,143</td>
<td>1,637,010</td>
<td>51.6</td>
<td>51.7</td>
</tr>
<tr>
<td>1997–1998</td>
<td>927,735</td>
<td>1,691,811</td>
<td>54.8</td>
<td>54.9</td>
</tr>
<tr>
<td>1998–1999</td>
<td>976,182</td>
<td>1,744,201</td>
<td>56</td>
<td>56.0</td>
</tr>
<tr>
<td>1999–2000</td>
<td>1,012,184</td>
<td>1,798,652</td>
<td>56.3</td>
<td>56.3</td>
</tr>
<tr>
<td>2000–2001</td>
<td>1,064,246</td>
<td>1,856,598</td>
<td>57.3</td>
<td>57.3</td>
</tr>
<tr>
<td>2001–2002</td>
<td>1,102,642</td>
<td>1,915,145</td>
<td>57.6</td>
<td>57.6</td>
</tr>
<tr>
<td>2002–2003</td>
<td>1,118,823</td>
<td>1,974,192</td>
<td>56.7</td>
<td>56.6</td>
</tr>
<tr>
<td>2003–2004</td>
<td>1,145,008</td>
<td>2,033,831</td>
<td>56.3</td>
<td>56.2</td>
</tr>
<tr>
<td>2004–2005</td>
<td>1,188,955</td>
<td>2,094,183</td>
<td>56.8</td>
<td>56.7</td>
</tr>
<tr>
<td>2005–2006</td>
<td>1,242,210</td>
<td>2,155,430</td>
<td>57.6</td>
<td>57.5</td>
</tr>
<tr>
<td>2006–2007</td>
<td>1,262,334</td>
<td>2,217,714</td>
<td>56.9</td>
<td>56.7</td>
</tr>
<tr>
<td>2007–2008</td>
<td>1,273,317</td>
<td>2,282,672</td>
<td>55.8</td>
<td>55.5</td>
</tr>
<tr>
<td>2008–2009</td>
<td>1,319,771</td>
<td>2,349,050</td>
<td>56.2</td>
<td>55.9</td>
</tr>
<tr>
<td>2009–2010</td>
<td>1,352,112</td>
<td>2,416,676</td>
<td>55.9</td>
<td>55.6</td>
</tr>
<tr>
<td>2010–2011</td>
<td>1,373,731</td>
<td>2,487,062</td>
<td>55.2</td>
<td>54.8</td>
</tr>
<tr>
<td>2011–2012</td>
<td>1,407,065</td>
<td>2,557,284</td>
<td>55</td>
<td>54.6</td>
</tr>
<tr>
<td>2012–2013</td>
<td>1,439,748</td>
<td>2,624,718</td>
<td>54.9</td>
<td>54.4</td>
</tr>
<tr>
<td>2013–2014</td>
<td>1,456,822</td>
<td>2,687,296</td>
<td>54.2</td>
<td>53.7</td>
</tr>
<tr>
<td>2014–2015</td>
<td>1,493,154</td>
<td>2,738,328</td>
<td>54.5</td>
<td>54.0</td>
</tr>
<tr>
<td>2015–2016</td>
<td>1,537,503</td>
<td>2,782,763</td>
<td>55.3</td>
<td>54.7</td>
</tr>
</tbody>
</table>

Data for 2015 to 2016 are preliminary; data for all other reporting periods are final. (a) ‘Participants’ are the number of women aged 50 to 69 screened through BreastScreen Australia in each two-year reporting period. The reporting periods cover 1 January of the initial year to 31 December of the latter year indicated; (b) ‘Population’ is the average of the Australian Bureau of Statistics (ABS) estimated resident population, for women aged 50 to 69, for the two reporting years; (c) ‘Crude rate’ is the number of women aged 50 to 69 screened in each two-year reporting period, as a percentage of the ABS estimated resident population; (d) ‘Age-standardised (AS) rate’ is the number of women aged 50 to 69 screened in each two-year reporting period, as a percentage of the ABS estimated resident population, age-standardised to the Australian population at 30 June 2001.

Australian Institute of Health and Welfare (AIHW) analysis of BreastScreen Australia data.
Cancer screening services in Australia are principally located in capital cities, however, 30% of the population live in rural and remote areas (Jiwa et al., 2007). BreastScreen Australia provides fixed location and mobile breast screening services. The mobile services extend the mammography services beyond the major cities. As a result, participation in breast screening within Australia varies spatially with participation for women aged 50 to 74 highest in outer regional areas at 57.2%, compared with 51.8% in Major cities and 46.6% in very remote areas (Table 2) (Australian Institute of Health and Welfare, 2017).

Therefore, travel time to the nearest breast screen service can affect participation rates. Bashshur et al. (1971) suggested that distance to a source of care affected frequency of use, with increased distance usually reducing use of services. A common measure of geographic access is the distance from a client to a facility (Rushton, 1999). Inherent in any assessment of geographical access is a measure of distance that represents the geographical separation, in distance, time or cost, between people and services (Cromley and McLafferty, 2002). Phibbs and Luft (1995) argued that studies of hospital demand and choice of hospital have often adopted a ‘straight line distance’ from the patient’s home to hospitals in order to measure access but this may not reflect travel time. Damiani et al. (2005) found that ‘very high’ correlations allowed the inference that straight line distance was indeed a reasonable proxy for travel time in most hospital demand or choice models but that travel time was only one measure of accessibility. Although distance is a fundamental indicator of geographical access, travel time, cost, transportation access, and perceived distance are often more relevant to health care utilisation (Cromley and McLafferty, 2002).

The relationship between accessibility and travel time to a breast screen service can be seen in the work by Onitilo et al. (2014) who assessed the number of missed mammograms with respect to time to the nearest facility (Table 3). Onitilo et al. (2014) observed significantly different travel times between women who missed none and those that missed five of their past annual mammograms. As can be seen in Table 3, the women who missed five of their past five mammograms had a median travel time of 27 min to a breast screen service facility ($p<0.0001$) (Onitilo et al., 2014). However, women who did not miss any of their annual mammograms lived a median of 15 min from the nearest breast screen service.

### Table 2. BreastScreen Australia participation by Australian Bureau of Statistics remoteness area, women aged 50 to 69 and women aged 50 to 74, 2014 to 2015.

<table>
<thead>
<tr>
<th></th>
<th>Major cities</th>
<th>Inner regional</th>
<th>Outer regional</th>
<th>Remote</th>
<th>Very remote</th>
<th>Australia (a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-69 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>986,514</td>
<td>325,979</td>
<td>153,749</td>
<td>17,713</td>
<td>8,036</td>
<td>1,493,154</td>
</tr>
<tr>
<td>Crude rate (b)</td>
<td>53.0</td>
<td>57.6</td>
<td>58.7</td>
<td>53.5</td>
<td>46.9</td>
<td>54.5</td>
</tr>
<tr>
<td>AS rate</td>
<td>52.6</td>
<td>56.7</td>
<td>58.0</td>
<td>53.3</td>
<td>47.0</td>
<td>54.0</td>
</tr>
<tr>
<td>50-74 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>1,118,627</td>
<td>376,955</td>
<td>176,191</td>
<td>19,992</td>
<td>8,838</td>
<td>1,701,854</td>
</tr>
<tr>
<td>Crude rate (b)</td>
<td>52.2</td>
<td>56.9</td>
<td>57.8</td>
<td>53.3</td>
<td>46.7</td>
<td>53.7</td>
</tr>
<tr>
<td>AS rate</td>
<td>51.8</td>
<td>56.2</td>
<td>57.2</td>
<td>53.1</td>
<td>46.6</td>
<td>53.2</td>
</tr>
</tbody>
</table>

(a) Includes women in the ‘not stated’ category; therefore, columns may not sum to the Australia column; (b) ‘Crude rate’ is the number of women screened in 2014 to 2015 as a percentage of the ABS estimated resident population; ‘age-standardised (AS) rate’ is the number of women screened in 2014 to 2015 as a percentage of the ABS estimated resident population, age-standardised to the Australian population at 30 June 2001; (c) Remoteness areas were assigned using the woman’s residential postcode according to the Australian Statistical Geography Standard (ASGS) for 2011. Not all postcodes can be assigned to a remoteness area, therefore categories do not add exactly to the total for Australia. Caution is required when examining differences across remoteness areas.

AIHW analysis of BreastScreen Australia data.
Spatial science has a clear role in determining the geographic accessibility of breast screen services in Australia. As Field and Briggs (2001) suggested, the ability to identify and measure spatial variations in need, access, and provision, and determine their effect on utilisation is therefore vital to inform the decisions of individual service providers and to help plan a national service that reduces inequalities in health outcome.

**Methods**

Location information on individual breast screen services in New South Wales, Australia were obtained from the Breast Screen New South Wales website (www.breastscreen.nsw.gov.au/) on the 1 February 2017. Street addresses for each of the breast screen services were geolocated using www.gps-coordinates.net/ and the longitude and latitude were recorded in decimal degrees.

Travel time to the geolocated health facility points was then calculated using the approach defined in the study of Weiss et al. (2018). In brief, this method estimates the time required to travel through each 1 km×1 km pixel on the earth and then determines the shortest travel time to the nearest point of interest (in this case the breast screen service facilities).

This approach utilised many geospatial data sets as inputs for estimating how quickly people can move through space (Weiss et al., 2018), with the roads layer being the most critical for defining travel times, particularly in industrialised nations like Australia. This method results in travel time surfaces (or maps) for further analyses.

To assess travel time within the population we analysed the geographic distribution of people as estimated by the WorldPop project (Gaughan et al., 2013) relative to the travel time surface. This was accomplished by stratifying the accessibility surface into 10-min intervals and summing the population in each stratum. The proportional of the population within the strata was then derived by dividing the total population in each time range by the total population of NSW. The resulting tabular data were converted into a cumulative percentage plot to show the distribution of the population relative to travel time to breast cancer screening facilities. By creating three versions of the travel time surfaces and conducting the population versus travel time assessment for each (i.e., mobile facilities, fixed facilities, and all facilities) the improved coverage provided by mobile facilities (as indicated by reduced travel times) is evident.

**Results**

The generated surface of travel time to breast screen services in New South Wales reveals that much of the coastal region of New South Wales has a travel time of 30 min or lower to a breast screen service (Fig. 1). The dark blue region on the right-hand side of the map is The Great Dividing Range which is inaccessible and is very sparsely populated. The surface also reveals that the population has several breast screen services options within an hour’s travel time.

Cumulative population curves reveal that over 90% of the population are within 20 min’ drive time of either a fixed or mobile breast screen service and that 100% of the population are within 100 min’ drive time of a breast screen service (Fig. 2).

**Discussion**

The generated surface of travel time to breast screen services in New South Wales has shown that over 90% of the population were within 30 min’ drive time of either a fixed or mobile breast screen service and that 100% of the population were within 100 min’ drive time. An increase in travel between a service and a patient’s residence is expected to lower utilisation.
Figure 1: The travel time to New South Wales breast screen services.

Figure 2: Geographic accessibility to breast cancer screening services in New South Wales.
The Use of Travel Time to Measure Geographic Accessibility to Breast Screening Services in New South Wales, Australia

(STARMANS et al., 1997). With a participation rate of 56.2% which is well below the breast screen programs target of 70%, further investigation into client travel to breast screen services is required. Exworthy and Peckham (2006) identified that distance-decay models vary according to patient characteristics (including age, gender, ethnicity, socio-economic status), service organisation (notably existing provision), and disease/illness condition (both in the condition and its severity).

The map presented here illustrates an approach that can readily be applied to public health analyses where travel time is hypothesised to influence patient behaviour. This is particularly true in developing countries where average travel times to facilities will typically be longer and/or the number and spatial distribution of healthcare facilities may be insufficient to effectively serve the population. While the results of this work suggest that travel time may not be a current impediment for women seeking breast screening in NSW, by enumerating this factor it can be thoroughly assessed within wider analyses attempting to isolate socio-demographic covariates associated with women not being screened.

Conclusion

The ability to identify and measure spatial variations in access and provision utilisation is vital to plan a service that reduces inequalities in health outcomes. However, the generated surface of travel time to breast screen services in New South Wales has also revealed that travel time to a breast screen service may not be the most significant factor affecting attendance at breast screen services.

It is well known that in reality, people trade off geographical and nongeographical factors in making decisions about health service use (Cromley and McLafferty, 2002). Therefore, this research has highlighted the need to analyse the accessibility of breast screen services beyond geographical access. As distance-decay varies according to patient characteristics (including age, gender, ethnicity, socio-economic status), service organisation (notably existing provision), and disease/illness condition (both the condition and its severity) (Exworthy and Peckham, 2006). Van Gaans and Dent (2018) have stated that older Australians accessibility to health services varies according to an older person’s geographical local and their accessibility to transport, as well as their level of multi-morbidity and cultural background. Understanding the accessibility of breast screen services has the potential to improve increase early detection and reduce breast cancer mortality.

Limitations

Private breast screening services have not been included in this research as they are not accessible to all. Therefore, the resulting map shows geographic access to public health services only.

Glossary

ABS Australian Bureau of Statistics
AIHW Australian Institute of Health and Welfare
AS Age-standardised Rate
ASGS Australian Statistical Geography Standard

Declarations

Ethics approval and consent to participate: Not applicable.

Availability of data and material: The accessibility map is available from https://map.ox.ac.uk/research-project/accessibility_to_cities/ and the location of breast screen services in New South Wales, Australia is available from https://www.breastscreen.nsw.gov.au/

Competing interests: None.

Funding: None.

Authors’ contributions: DvG and DJW drafted the manuscript. NC, TN, MD, DMR, DJW, CM, MWS and DVG reviewed and revised the manuscript. All authors read and approved the final manuscript.

Acknowledgments

The authors would like to acknowledge the support provided by the Cancer Institute New South Wales.

References


